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PETER HESSEL, C.Tran. (Canada)

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(2) that I have translated into English:
Abstract, description and claims of
Patent DE 102 48 644.1 (PA17 2002 DE)

(3) that the translation is to the best of my knowledge and belief an accurate translation from the original into the English language.

I, the undersigned declare further that all statements made herein of my own knowledge are true and that all statements made of information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the matter with which this translation is used.

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this 30th day of September, 2003

Peter Hessel,
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Statutes of Ontario, 1989, Chapter P r 2
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Power semiconductor module

Abstract

The invention relates to a power semiconductor module, in particular a power converter module, with a base plate or for direct installation on a heat sink. The power semiconductor module consists of a packaging, at least one power semiconductor component (4) and at least one insulating substrate (2) on whose first surface a metallic layer (3) is provided. Carbon nano tubules (6) are used for the thermal and partly electrical contacting, on the one side for contacting the power semiconductor component (4) with the metallic layer (3) and on the other side to connect the substrate (2) with the heat sink (1).

(Fig. 1)

Description

The invention relates to a power semiconductor module, in particular a power converter module, with a base plate or for direct installation on a heat sink, with active and/or passive components. Several such power semiconductor modules are known from the literature. When the capacity is increased, especially by using modern power semiconductor components with higher cooling requirements, other methods of configuration technology are absolutely necessary for the individual parts.

Modern power semiconductor modules, which are the starting point of this invention, are modules without base plates, such as described in DE 199 03 875 C2, consisting of

- a packaging,
- a ceramic substrate with circuit-friendly metallic laminations such as those made according to the DCB (direct copper bonding) method;
- components positively bonded to this substrate by soldering, such as diodes, transistors, resistors or sensors;
- bonds to connect the structured side of the components with other components, the substrate and/or connecting elements leading outside;

- a sealing compound preferably made of silicon rubber, to insulate the individual components from each other.

A configuration technology with pressure contact for the thermal contacting of the module on a heat sink has proven very advantageous for such power semiconductor modules. It has been shown that in particular the quality of large-surface soldering bonds is very difficult to control, which is detrimental to the reliability and service life of the power semiconductor modules.

Preferably, the pressure configuration in such pressure-contacted power semiconductor modules is achieved with a mechanically stable pressure plate. Depending on the further development, the generated pressure can be transmitted to the substrate either by means of special pressure plate designs (as shown, for example, in DE 196 48 562 C2) or by means of an elastic pressure accumulator according to DE 199 03 875 C2.

In such pressure-contacted power semiconductor modules, a heat-conducting medium is provided to establish full-surface thermal conduct and thus to compensate for any unevenness on the heat sink and/or the substrate underside between the power semiconductor module and the heat sink.

The power semiconductor modules according to DE 196 48 562 C2 or DE 199 03 875 C2 as well as power semiconductor modules known in prior art, with a base plate or for direct installation on a heat sink, have the disadvantage that heat dissipation to a cooling element or cooling body such as a heat sink is subject to high thermal resistance. The more marginal areas exist between the power semiconductor module generating the heat and the heat sink, the greater the thermal resistance. In comparison with metals, flexible thermally conducting layers such as heat-conductive paste, have clearly higher heat resistance. Therefore, the efficient dissipation of heat from a power semiconductor module to a heat sink is a substantial component of highly efficient compact configuration topologies.

Another disadvantage of power semiconductor module with a base plate or for direct installation on a heat sink according to prior art is that the modern power semiconductor components used have a higher current load capacity per chip area and also produce more waste heat per unit of area. The connection between an advantageously metal-laminated substrate and the power semiconductor component is already a limiting factor for the efficiency of a power semiconductor module. At present, the heat generated in the power semiconductor component can still be dissipated by means of existing connection methods, usually soldering bonds. In future chip generations, the thermal conductivity of the connection between the power semiconductor component and the substrate will have an even more limiting effect on

efficiency. Furthermore, the connections named above are at the limit of their current load capacity. In that respect, too, the electrical connection between the power semiconductor component and the substrate will determine the efficiency of the power semiconductor module.

The object of the present invention is to present a power semiconductor module in which the electrically and thermally conductive connection between at least one power semiconductor component and the substrate and/or the thermally conductive connection with a heat sink has a reduced thermal and if necessary also electrical resistance.

This object is achieved by means of the characteristics of Claim 1. Other preferred embodiments are described in the subclaims.

Carbon nano tubules as an electrically and thermally highly conductive material have been known from many research studies and, for example, from DE 101 03 340 A1. It is also known that such carbon nano tubules are preferably running in the direction of the tube. In this preferred direction, the carbon nano tubules (if properly designed) have a lower thermal and electrical resistance than metals.

The basic concept of the invention is the use of such carbon nano tubules as thermally conductive and/or thermally and electrically conductive components within a power semiconductor module and/or from a power semiconductor module to a heat sink.

The power semiconductor module according to the invention, with a base plate or directly installed on a heat sink, consists of a packaging, at least one electrically and thermally contacted power semiconductor component and at least one insulating layer.

On the first surface of the substrate facing away from the base plate or the heat sink, a metallic layer is provided which preferably has a circuit-friendly structure, and on which at least one power semiconductor module is arranged. A layer of carbon nano tubules running substantially orthogonal to the substrate planes is provided as an electrically and thermally conductive connection between the power semiconductor component and the metallic layer.

Alternatively or as a supplement, the power semiconductor module according to the invention has another layer of carbon nano tubules which is arranged between the substrate and a heat sink, a cooling element or a base plate. This layer has a high thermal conductivity.

Special embodiments of the inventive solutions are explained with reference to Fig. 1 and 2. For the sake of simplicity, the packaging and the prior-art connections between the top surfaces of the components and the metallic layers, as well as the further connecting elements are not shown.

The figures show a cross section through a power semiconductor module with inventive characteristics in a configuration with a heat sink (1) or base plate (1). For that reason, the terms “base plate” and “heat sink” are used synonymously below.

Fig. 1 shows a heat sink (1) that is thermally conductively connected with the insulating substrate (2) by means of a layer of carbon nano tubules (5) running substantially orthogonal to the heat sink surface and epitaxially deposited on the heat sink. The layer of carbon nano tubules can also be epitaxially deposited on the substrate (2). For this purpose, it is advantageous to provide the substrate with a metallic layer (7 in Fig. 2) on its side facing the heat sink (1).That layer (7), as well as the metallic layer (3), can be applied on the side of the substrate (2) facing away from the heat sink (1), for example by means of the known DCB method. It can be advantageous if between the thus resulting copper layer and the layer of carbon nano tubules another layer (thinner than the copper layer) of another metal, preferably nickel, is arranged as bonding agent for the carbon nano tubules.

The carbon nano tubules are applied to the respective surfaces by means of a known methods such as that described in DE 101 03 340 A1.

The power semiconductor components (4) are arranged on the side of the substrate (2) that faces away from the heat sink (1). On their side facing the substrate (2) they are provided with a layer of carbon nano tubules (6) directly epitaxially deposited on the power semiconductor component (4).

Safe contacting of the power semiconductor components (4) on the metallic layer (3) is achieved by means of pressure-bonded contact (not shown). For this purpose, pressure is exerted on the top side of the power semiconductor component (4) by means of a suitable pressure element. Advantageously, an electrical contact can be achieved in this manner as well. Such a contacting method is known, for example, from DE 101 29 170 A1.

The entire power semiconductor module is also pressed onto the heat sink (1) by means of pressure-bonded contact, for example according to DE 101 29 170 A1, and thus thermally conductively connected with same.

Another embodiment of the thermally conductive connection between the substrate (2) and the heat sink (1) is shown in Fig. 2. Here, the carbon nano

tubules are not arranged in a combined bond as described above, but embedded in a bonding agent such as a silicon oil (AKF 1000 by Wacker) as individual tubules or groups of tubules. This pasty mixture (8) is applied between the substrate (2) and the heat sink (1) in the same manner as customary heat-conductive pastes known in prior art. An advantage of the embodiment according to the invention is that this pasty mixture is less thermally conductive than the prior art by at least 2 orders of magnitude.

Claims

1. Power semiconductor module with a base plate (1) or for direct installation on a heat sink (1), consisting of a packaging, at least one power semiconductor component (4) and at least one insulating substrate (2) on whose first surface a metallic layer (3) is provided, whereby the at least one power semiconductor component (4) is connected with the metallic layer (3) by means of a layer of carbon nano tubules (6) running substantially orthogonal to the substrate planes, and/or
whereby the substrate (2) is connected with the base plate (1) or the heat sink (1) by means of a layer of carbon nano tubules (5, 8).

2. Power semiconductor module according to Claim 1 characterized in that an additional metallic layer (7) is provided on the second main surface between the substrate (2) and the layer of carbon nano tubules (5, 8).

3. Power semiconductor module according to Claim 1 characterized in that at least one Power semiconductor component (4) including its carbon nano tubules is positively bonded to the substrate (2) by means of pressure contact.

4. Power semiconductor module according to Claim 1 characterized in that the power semiconductor module is arranged on the base plate (1) or the heat sink (1) by means of pressure contact.

5. Power semiconductor module according to Claim 1 characterized in that the carbon nano tubules (6) are arranged directly on the power semiconductor component (4).

6. Power semiconductor module according to Claim 1 characterized in that the carbon nano tubules (5, 6) are arranged on at least one metallic layer (3, 7) of the substrate (2).

7. Power semiconductor module according to Claim 1 characterized in that the carbon nano tubules (5) are arranged substantially orthogonal to the substrate plane.

8. Power semiconductor module according to Claim 1 characterized in that the carbon nano tubules are arranged between the substrate (2) and the base plate (1) or the heat sink (1) in a pasty mixture (8) of carbon nano tubules and a bonding agent such as a silicon oil.